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HEAT STRESS CAUSED BY WEARING DIFFERENT TYPES OF CW PROTECTIVE GARMENT (U)

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DEFENCE RESEARCH ESTABLISHMENT OTTAWA

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ABSTRACT

One means of reducing the heat stress caused by wearing protective clothing is to eliminate the air layers between the skin and layers of the ensemble. In order to evaluate the effectiveness of this concept, four unacclimated males wearing either the current Canadian Forces (CF) chemical protective overgarment, an individually-tailored skintight protective garment or CF combat uniform participated in a series of experiments conducted at 40°C and low relative humidity. Each was instrumented with a rectal thermistor, donned the clothing and walked on a treadmill at 5 km hr^{-1} and 2% grade for 90 min, until his rectal temperature reached 39°C or he requested to withdraw from the experiment. The results of this preliminary investigation indicate that there appears to be some advantage to wearing the skintight clothing under these conditions.

RÉSUMÉ

Une des façons de réduire le stress thermique causé par le port d'habillement de protection est d'éliminer les couches d'air entre la peau et les couches d'habillement. Pour évaluer l'efficacité de ce concept, quatre mâles non acclimatisés portant soit l'habillement de protection chimique des Forces Canadiennes actuel, un habit de protection moulant ajusté individuellement ou l'uniforme de combat des Forces Canadiennes ont participés dans une série d'expériences à 40°C et humidité relative basse. Chacun fut instrumenté d'un thermistor rectal, et a marché habillé sur un tapis roulant à 5 km hr^{-1} avec une pente de 2% pendant 90 minutes, ou jusqu'à ce que sa température rectale atteigne 39°C ou qu'il demande d'arrêter l'expérience. Les résultats de cette investigation préléminaire indiquent qu'il semble y avoir un avantage à porter un vêtement moulant sous ces conditions.

EXECUTIVE SUMMARY

A major problem associated with wearing chemical warfare (CW) protective clothing is the increased susceptibility to heat stress of the wearer. It has been suggested that skintight clothing would provide less resistance to heat loss and thus reduce this problem. Since the Canadian Forces became involved in the Middle East in late 1990 it was decided to examine this concept.

Subjects were exposed to an environment of 40°C and 25% relative humidity while walking on a treadmill at 5 km hr^{-1} while dressed in one of the following ensembles:

1. undershorts, CF combat shirt, trousers,wool socks and combat boots
2. undershorts, CF CW protective overgarment, C-4 gas mask, CW gloves, socks and combat boots
3. undershorts, C-4 mask, CW gloves, socks, combat boots, solarmax long underwear and a two piece tight fitting charcoal impregnated lycra suit. The head was covered with a hood made from the lycra material.

Each subject wore each of the ensembles twice.

A second series of experiments, using the same protocol but with an additional clothing configuration (ensemble 2 plus combat clothing) in place of ensemble 1, were performed. After completing the protocol the subjects entered the laboratory at 24°C and their core temperatures were measured as they cooled without removing their protective clothing.

The results indicate that there appears to be an advantage to wearing the skintight clothing while working under the given ambient conditions since the body temperatures of the subjects rose more slowly in this clothing than in the current CW clothing. These results are not surprising since the thermal insulation of the close-fitting material itself is less than that of the CW coverall material, without considering the reduction caused by eliminating the air layers. Some of the subjects dressed in the overgarment dropped out of the experiment for reasons other than the rise in core temperature. Also, the subjects cooled faster in the skintight clothing than in the other ensembles.

Further work should be done to determine if it is feasible to replace the current overgarment with a closely fitting one to be worn at high ambient temperatures.

INTRODUCTION

Wearing chemical warfare (CW) protective clothing under most conditions imposes restrictions and reduces the efficiency of the wearer. One of the major problems associated with the wearing of the Canadian Forces (CF) CW protective overgarment is the increased susceptibility to heat stress since the coveralls increase the amount of thermal insulation and prevent the evaporation of perspiration, inhibiting body heat loss to the environment.

Farnworth and Crow (1) have suggested that one of the factors contributing to the heat stress caused by wearing CW clothing is the fact that the garment is loose-fitting and that the air layers between the skin, underwear and CW suit all contribute to the total thermal insulation of the ensemble. Theory indicates that if the air layers were removed, the thermal insulation would be reduced significantly. Farnworth and Livingstone (2) have shown that close-fitting garments do not provide as much insulation as loose-fitting garments when worn in cold conditions. As the Canadian Forces became involved in the Middle East in late 1990, it was decided to perform a series of experiments to determine the effects of wearing close-fitting clothing on the onset of heat stress while working in hot conditions.

METHODS

Three different clothing ensembles were examined. The first consisted simply of undershorts, CF combat shirt, trousers, wool socks and combat boots. In the second, shorts, CF CW protective overgarment, C-4 gas mask, CW gloves, socks and combat boots were worn. For the third ensemble, a two-piece close-fitting suit manufactured using lightweight charcoal-impregnated lycra material was individually tailored to fit each participant. It was worn with a hood made of the same material, top and bottom long underwear (Solarmax), C-4 mask, CW gloves, socks and combat boots.

Three members of the DREO test team and one DREO civilian gave their informed consent to participate in the experiments. All were in reasonably fit physical condition and were unacclimated to the environmental conditions of the experiment. Their anthropometric characteristics are given in Table 1.

Table 1. Anthropometric characteristics of volunteers

Subject	Age (years)	Height (cm)	Weight (kg)
1	30	183	77
2	26	185	74
3	24	182	89
4	26	170	70

Each subject first sat quietly for one hour in an environmental chamber at 40°C and 25% relative humidity after which he left the chamber and inserted a rectal thermistor 15 cm into the anus. He then dressed in one of the three different clothing ensembles (chosen at random) and re-entered the environmental chamber. He then walked on a treadmill at 5 km hr^{-1} and 2% grade for 90 min, until his rectal temperature reached 39°C or he requested to withdraw from the experiment. The experiment was repeated once with each clothing configuration, making a total of six exposures for each participant. At least 48 hours elapsed between repeats, in an attempt to prevent the volunteers from becoming acclimatized.

During the experiment the subject's rectal temperature was measured and recorded every minute using an automated data acquisition system (Hewlett-Packard 3497A) and HP 85 computer. All data were stored for subsequent analysis. Each subject was allowed water ad libitum.

A second series of experiments repeated the protocol of the first series using different clothing configurations. In this series, combat clothing worn under the CW ensemble was added and combat clothing worn alone was not tested. After completing the protocol at 40° C, the subjects left the chamber and sat in the laboratory at 24° C without removing their protective clothing or mask. Rectal temperature continued to be measured and recorded for several minutes, until it had dropped approximately 1° C. Only three subjects participated in this series.

RESULTS

Because of the limited number of subjects tested and because of the known variability of physiological responses among subjects (Armstrong et al (3)), individual responses are shown rather than statistical means of the results.

Changes in rectal temperature as a function of time when wearing the different types of clothing are shown in Figure 1, where CW, CO and SK indicate chemical protective, combat and skintight clothing, respectively. The cooling curves of the second series of experiments are shown in Figure 2 where CWC indicates combat clothing worn under the CW garment. Subject 3 did not perform the experiment when wearing only CW clothing.

A summary of individual results is given in Table 2, which lists maximum rectal temperature observed (Tmax), the change in rectal temperature (ΔT), the duration of each experiment (time) and rate of temperature rise (ΔT/time).

With the exception of subject 1, who warmed fastest when wearing the CW ensemble and slowest when wearing the combat clothing, it is apparent that consistent results were not obtained with the other subjects. However, an analysis of rate of temperature rise (ΔT/time) indicates that there were significant differences between the clothing ensembles i.e. rectal temperature increased most rapidly when CW protective clothing was worn and least rapidly with the combat clothing alone. As shown in Table 2, the reason for terminating the experiment was not always because maximum time or temperature limits were reached. This indicates that wearing the CW clothing created additional problems, causing the subjects to abort the experiments earlier than when wearing the other ensembles.

The rectal temperatures measured during cooling (Fig. 2) indicate that the subjects cooled most rapidly in the close fitting clothing and least when wearing the CW clothing plus combat clothing. These results also indicate that wearing the skintight clothing is beneficial.

DISCUSSION

The results indicate that there appears to be an advantage to wearing the skintight clothing while working under the given ambient conditions. Subjects' rectal temperatures increased by similar amounts but at different rates when wearing the different ensembles. When resting at a lower ambient temperature, the subjects cooled faster when wearing the close-fitting clothing. These results are not surprising since the thermal insulation of the close-fitting material itself is less than that of the CW coverall material, without considering the reduction caused by eliminating the air layers.

Results also indicate that change in rectal temperature was not the only parameter which caused subjects to withdraw from the experiment. Several times subjects complained of feeling too hot and having trouble breathing. Similar observations have been reported by Armstrong et al (3). As seen in Table 2, with one exception, these complaints occurred only when the CW coveralls were worn. A more detailed study should be done to determine the reason.

Our experiments did not attempt to simulate the effects of the radiative heat input from the sun, a very real factor in the desert which would increase the severity of the conditions under which the protective clothing would have to be worn. It may also be difficult in the desert to find cool areas in which to rest. Thus, the cooling effect of resting for the times indicated in Figure 2 would not necessarily alleviate the heat stress as shown. However, resting might possibly reduce the rate of increase of body heat.

CONCLUSIONS

The results of this preliminary investigation indicate that there appears to be some advantage to wearing the skintight clothing under these conditions. They also indicate that additional work is required to determine why some subjects aborted the experiment before their rectal temperature reached 39° C when wearing the CW overgarment. Further investigation is alsc necessary to determine if it is feasible to replace the current CW protective overgarment with a more closely fitting one, resulting in less heat stress when worn at high ambient temperatures.

REFERENCES

1. B. Farnworth and R. Crow. "Heat stress in chemical clothing." Technical Note 83-28, Defence Research Establishment Ottawa, Ottawa, Ontario, 1983.

2. B. Farnworth and S.D. Livingstone. "The thermal resistance of the CF CW suit." Technical Note 85-22, Defence Research Establishment Ottawa, Ottawa, Ontario, 1985.

3. L.E. Armstrong et al. "Prediction of the exercise-heat tolerance of soldiers wearing protective overgarments." Aviat. Space Environ. Med. 1991; 62:673-7.

TABLE II
Comparison of the Three Clothing Ensembles

	Combat Clothing				CW Overgarment				Skintight Clothing			
Subject	Tmax (°C)	▲T	t (min)	▲T/t	Tmax (°C)	▲T	t (min)	▲T/t	Tmax (°C)	▲T	t (min)	▲T/t
1 A	38.1	0.7	90	0.008	39.0	2.0	89 *	0.022	38.9	1.3	90	0.014
B	38.3	1.1	90	0.012	38.9	1.8	82	0.022	38.6	1.2	90	0.013
2 A	38.5	1.9	90	0.021	39.0	2.3	71 @	0.032	38.1	2.2	90	0.024
B	38.0	1.3	90	0.014	37.7	1.0	74	0.014	38.2	1.5	90	0.017
3 A	38.4	0.8	89	0.009	38.5	1.5	68 #	0.022	38.8	1.5	90	0.017
B	38.2	1.1	90	0.012	38.5	1.4	61 #	0.023	38.8	1.5	70 +	0.021
4 A	38.2	1.1	90	0.012	39.0	1.8	54 ~	0.033	39.0	2.1	88	0.024
B	38.5	1.4	90	0.016	38.3	0.8	45	0.018	38.4	1.4	90	0.016
mean	38.3	1.2	89.9	0.013	38.6	1.6	68.0	0.023	38.6	1.6	87.3	0.018
S.D.	0.2	0.4	0.3	0.004	0.5	0.5	14.4	0.006	0.3	0.4	7.0	0.004

* choking feeling
@ hot, trouble breathing
\# couldn't breath
\+ legs numb, trouble breathing
~ hot, dizzy

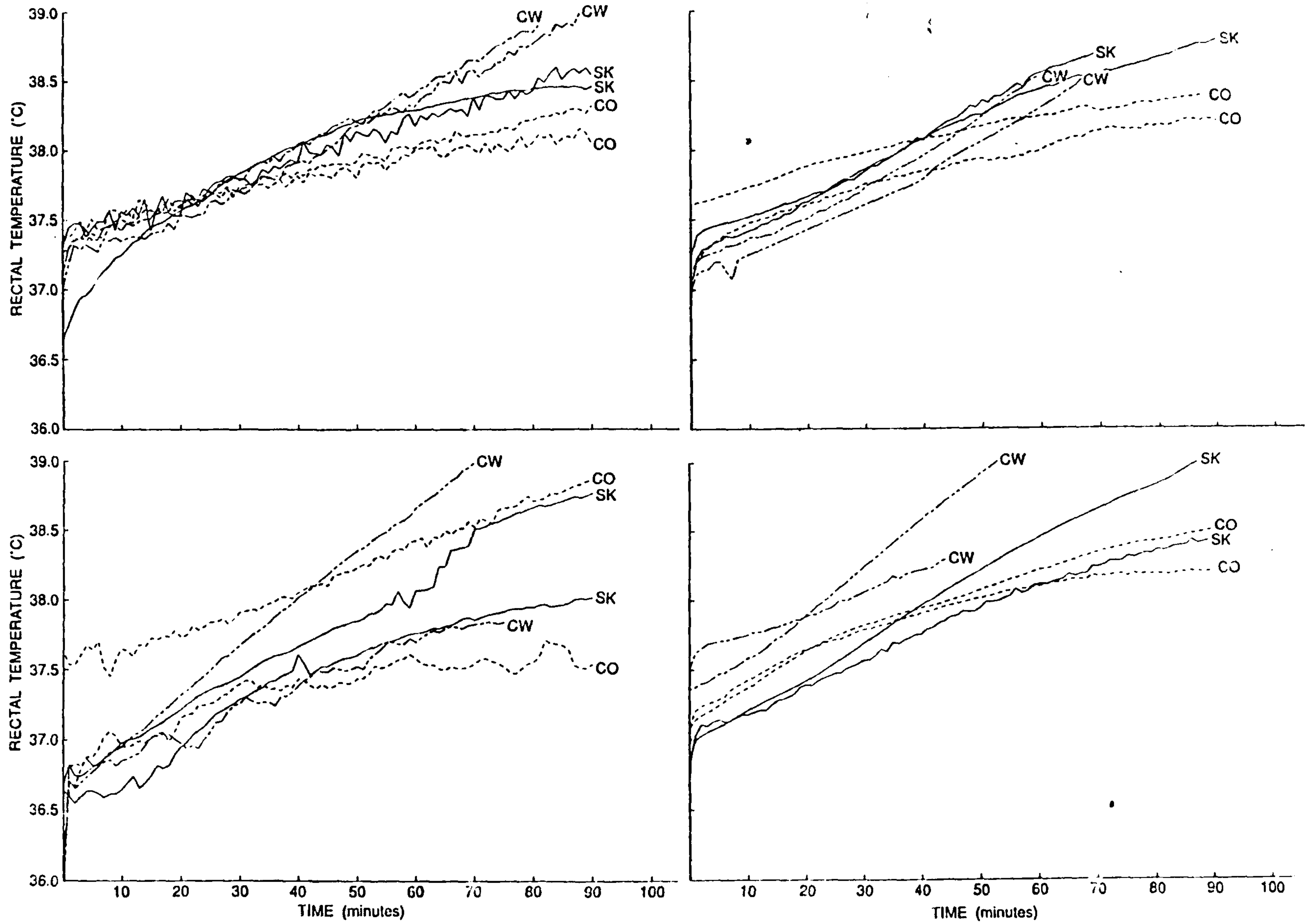

Fig. 1: Changes in Rectal Temperature of Each Subject as a Function of Time When Wearing the Different types of Clothing. CW, CO and SK Indicate Chemical Protective, Combat and Skintight Clothing, Respectively.

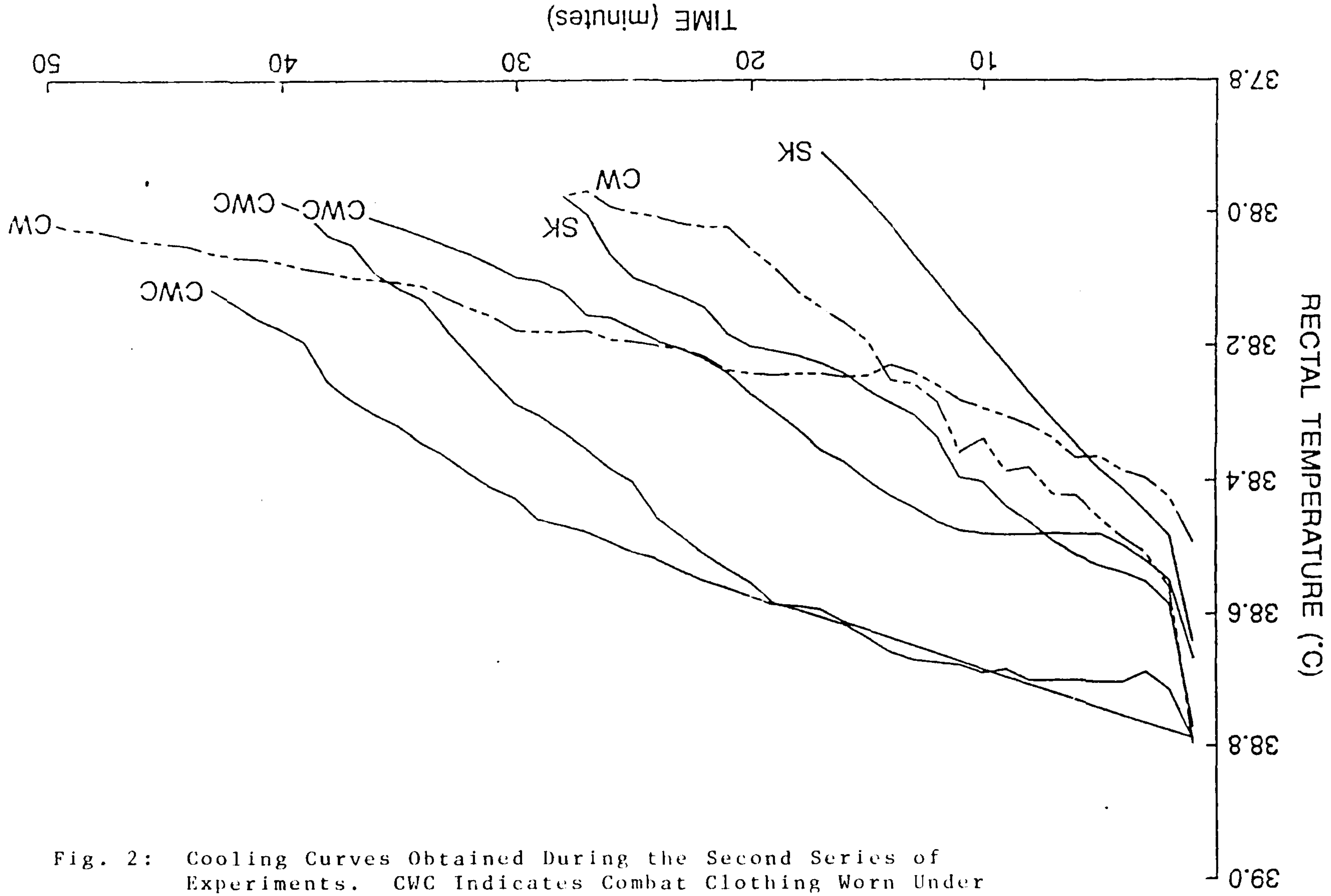

Fig. 2: Cooling Curves Obtained During the Second Series of Experiments. CWC Indicates Combat Clothing Worn Under the CW Garment.

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Skintight Clothing
Body Temperature
Hot Ambient Temperature
Chemical Protective Overgarment